CEMENT AND LIME

MANUFACTURE

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Properties of Cements and Limes Submitted to High Pressures.

By DR. F. JAGER.

THE action of temperature on hydraulic binding materials has been the subject of numerous investigations, particularly in recent years, but up to the present the effect of pressure does not seem to have been studied. For this reason the principal types of hydraulic binding materials have been submitted to increasing pressures up to as much as 18,000 kg. per sq. cm., the limit imposed by the strength of the steel available. It has been proved that the sets and strengths of these binding materials are sensibly increased by increasing pressures of the order of 9,000 kg. per sq. cm. Above these pressures the improvement fell off.

These observations seem to be capable of explanation by the crushing of the material which occurs at a high pressure, but above which the material tends to unite again. The tests have been made at the laboratory of Cimenterie de l'U.C.P.M.I.

It seemed that it would be of interest to study the action of very high pressures (up to several tens of thousands of kilogrammes per square centimetre) on powders. It has been thought that very high pressures ought to produce changes in the speed of chemical reaction of powders, and in order to verify this the action of pressure on a certain number of hydraulic binders has been studied. The arrangement for making the tests was simple. On the horizontal platform of an Amsler 100-ton testing machine, a steel cylinder was placed with its axis vertical and filled with the powder under test. A round steel bar having the same diameter as that of the cylinder (with a tolerance of 2 mm. to avoid binding) was used as a piston and compressed the material by acting with the second plate of the testing machine. By varying the diameters of the cylinder and

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piston, all pressures within the desired range were easily obtained. The effect of pressure was to compact the powder into a block which was apparently very hard but which could be crushed into dust again in the hand.

The following result of the tests has been observed. Hydraulic binders which have been submitted to high pressures undergo a molecular transformation which is greater as the pressure is greater and which completely changes the hydraulic properties of the material.

(1) The set is accelerated up to pressures of the order of 9,000 kg. per sq. cm. for slag cement (*ciment de laiter*). For pressures of the order of 18,000 kg. per sq. cm. the set is delayed.

(2) The rate of hardening is increased in such a way that with slag cement, for example, the compressive strength at two days is doubled with a pressure of 9,000 kg. per sq. cm. Above this pressure the strengths decrease. This law has been checked for artificial cement, blastfurnace cement, slag cement, plaster, and hydraulic lime.

The following are the strengths in compression found with slag cement, containing a base of artificial cement, two days after hardening and using a standard plastic 1 : 3 mortar.

	Strength in kg. per sq. cm.
Control specimen	66
Specimen compressed to 2,000 kg. per sq. cm. ..	85
,, ,, ,, 4,000 ,, ,, ,, ,, ..	100
,, ,, ,, 9,000 ,, ,, ,, ,, ..	120
,, ,, ,, 18,000 ,, ,, ,, ,, ..	108

Another interesting fact noticed was that the finenesses of cement, measured on a sieve with 10,000 meshes to the square centimetre, increased slightly at first with pressure but decreased suddenly at 18,000 kg. per sq. cm.

	Percentage left on sieve with 10,000 meshes per sq. cm.
Control specimen	12
Specimen compressed to 2,000 kg. per sq. cm. ..	12
,, ,, ,, 4,000 ,, ,, ,, ,, ..	10.5
,, ,, ,, 9,000 ,, ,, ,, ,, ..	10.5
,, ,, ,, 18,000 ,, ,, ,, ,, ..	16

At 9,000 kg. per sq. cm. the portion left on the sieve was composed of small grains massed together, but at 18,000 kg. per sq. cm. the remainder on the sieve was composed almost entirely of grains of several millimetres diameter.

For plaster the following results have been found :

	Set		Strength in compression (kg. per sq. cm.) after one day.
	Initial.	Final.	
Control specimen	6 min.	9 min.	82 kg.
Specimen compressed to 2,000 kg. per sq. cm.	3 ,,	5 ,,	102 ,,
Specimen compressed to 4,000 kg. per sq. cm.	2 ,,	4½ ,,	113 ,,

At first it was thought that these phenomena might be due to the increase in temperature caused by the work done in compressing the materials. The work necessary to press 50 gr. of cement from 0 to 9,000 kg. per sq. cm., with a piston 6 sq. cm. in section, is about 240 kg.-m. measured on the Amsler machine. If it is assumed that all the work is changed into heat in the cement, and that the specific heat of cement is 0·2, the temperature of the cement at the end of the period of compression should be increased by about 20 deg. C., but the temperatures actually measured were much below this figure and it does not appear reasonable to assign to temperature the changes in properties which have been observed.

M. Travers has put forward the theory that the phenomena observed might be due to the release of air from the powder. To check this, some specimens of cement have been subjected to a pressure of about 3 mm. of mercury for 8 hours at the ordinary temperature. These specimens did not show any improvement in strength. On the contrary, an examination of the grading of the powder before and after compression showed that the proportion of very fine particles can be greatly increased by the pressure, and this is, in the writer's opinion, the real explanation of the facts observed during the experiments. Moreover, materials submitted to the action of high pressure break up so that the particles have a total surface per unit of weight much greater than is produced by any other method of grinding.

Summary.

The following general conclusions can be drawn from the preceding remarks.

(1) The compression of certain powders increases the speed of their chemical reaction.

(2) When the pressure increases the speed of reaction increases at first, then decreases, and becomes zero and finally negative at very high pressures.

(3) This increased speed of reaction appears to be due to an increase in the effective useful surface area of the powder which is produced by breaking up the particles under pressure. Above a certain limit of pressure the cements weld themselves together again and effects of the opposite kind tend to occur.

It would appear that the chemical industry could benefit from the preceding notes when the question arises of increasing the activity of certain powders.

Crushing Strength of Cement.

VARIATIONS in the strength of Portland cement were discussed by Mr. F. W. Sparkes (of the Road Research Laboratory) in a paper on "The Control of Concrete Quality," read at a meeting of the Society of Chemical Industry recently, in the course of which the lecturer said: Cement quality has normally been assessed from tests made in accordance with the requirements of British Standard Specification No. 12. As a result of much experience in employing these standard tests, it can be stated that only on rare occasions does a cement fail to satisfy the requirements. The tests do not, however, necessarily give an indication as to how the cement will behave when used in concrete. From this point of view a more acceptable test comprises a compression test upon cubes of 3 in. side, made from a 1 : 3 mortar using the particular cement and standard Leighton Buzzard cement-testing sand. The compressive strength of such specimens, when gauged with 12½ per cent. of water, approximates closely to that of a 1 : 2 : 4 concrete with 0.60 water-cement ratio made with the same cement. A similar compression test has been suggested in the United States and Italy. If cement is tested in this way it will be possible to estimate the quality of concrete made from it with much greater reliability than when the cement is tested in the ordinary manner. Consequently this method was employed in measuring the variations in cement quality.

While engaged in experimental work at the site of a road construction job, opportunity was taken to examine the variability in cement quality. The cement used was a normal Portland cement and was usually delivered to the site in lots of ten tons. Two samples were taken during the construction of each 30-ft. slab and tests made on 1 : 3 mortar test pieces. A total variation of 28 per cent. was recorded, and this variation will be reflected in the quality of concrete made with these cements. Occasional variations up to as high as 60 per cent. have been recorded at the Road Research Laboratory, but for purposes of computing the effect upon concrete quality an average figure of 30 per cent. is probably the more correct one.

After dealing with the causes of variations in the strength of concrete and methods of control, he summed up the contribution of variations in the constituent materials to the variability of the resulting concrete as follows:

(1) Variations in quality of cement may produce total variations from the mean in concrete made with it up to 30 per cent.

(2) The effect of possible variations in the grading of the aggregates may account for 20 per cent. or so in the variation of the concrete.

(3) The bulking of the fine aggregate may affect the concrete to the extent of some 10 per cent.

(4) Variations in the curing conditions may produce further variations, particularly at early ages.

(5) Inadequate consolidation of the concrete may reduce its strength by 30 per cent. or 40 per cent.

Placing Concrete After the Initial Set of Cement.

IN a recent number of "Concrete & Constructional Engineering," Mr. Russell V. Allin, M.Inst.C.E., describes experiments to ascertain the effect on the strength of concrete of remixing at various periods after the first mixing. He writes:

The term "pre-set" is used in this article to denote concrete which has attained a substantial measure of set before being placed in the work. Frequent use in specifications of the term "initial set," to define the degree of set which concrete may be allowed to attain before placing, has left in the minds of many the idea that there is something essentially injurious to its final strength in disturbing its set when placing.

In considering the subject it is helpful to recall the fact that the term "initial set" is a technical one used in connection with cement testing to indicate an arbitrarily chosen stage of setting at which a neat cement block, of prescribed water-cement-ratio made under specified conditions, presents a certain degree of resistance to a loaded needle. It, therefore, has little significance except as a means of comparison of the setting qualities of various cements. This term has still less practical value when applied to concrete, the setting properties of which are being constantly varied by such factors as the strength of the mix, the grading of the aggregate, and the amount of water used. It is therefore impossible to establish any definite relation between the "initial set" of the cement and that of the concrete from which it is made.

Experimental Results.

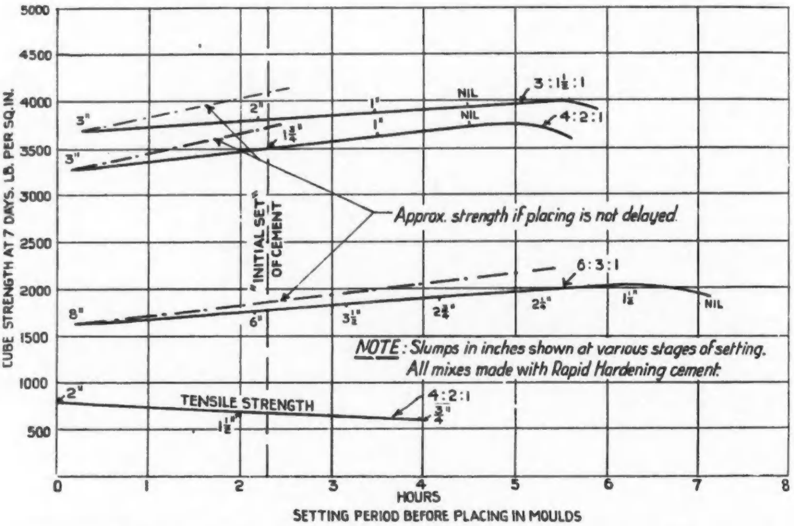
The writer has investigated the effect on the strength of concrete of allowing it to attain a partial set before placing. The investigations were carried out by comparing the seven-day strength of test cubes and small beams made with concrete of various mixes and slumps which had been allowed to set for various periods before punning it into the cube moulds. It was found that rapid-hardening and ordinary Portland cement concrete gave results of the same order and that the concrete behaved in regard to its increase of strength with time in the same way, whether it was placed immediately after mixing or had been allowed to obtain a substantial set before placing.

Contrary to the usual practice in making test cubes, the amount of punning in these cubes and beams was not kept uniform but adjusted in every case according to the set which the concrete had been allowed to reach before placing in the moulds, and the readiness with which punning restored the workability of the "pre-set" concrete, without addition of extra water, was noticeable. Loading tests to destruction on small monolithic beams, half of which had been made with "pre-set" concrete and half with concrete taken from the mixer, showed that there was usually a perfect marriage without a plane of weakness where the two concretes joined.

From the test results shown in the graph, which represents an average of many tests, it is seen that the setting and hardening processes are not interrupted

by the delay between mixing and placing, and that there is a slight improvement in the seven-day compressive strength of the concrete, as the slump (taken immediately before placing it in the mould) decreases with the delay, except where, as seen at the end of the curve, it has been allowed to set so long as to preclude restoration of its workability and satisfactory compacting by punning.

There is also seen to be a slight falling off (as the delay was increased) of the tensile strength at which the beams failed under load, but so little as to be of no practical importance. It is further seen that the improvement in compressive strength (effected by delay) was not as great as would have been obtained by originally reducing the water-cement-ratio of the concrete, this improvement



probably being due to the fact that a portion of the water surplus to the requirements of hydration is allowed to drain away and evaporate on the banker during the period of delay in placing although a portion probably remains trapped in the concrete.

Conclusions.

To sum up, it is clear from these experiments that (1) there is nothing essentially injurious to the strength of concrete in breaking its set, as such, provided it is allowed to retain the workability necessary for satisfactory compacting, and that (2) there is no definite relation between the period of "initial set" of the cement and the amount of delay in placing which can be safely allowed. A recognition of these facts is of considerable practical importance in providing a logical approach to the question of the delay permissible between mixing and placing, and also because the use of "pre-set" concrete has several other practical applications, notably in regard to under-water work.

In the case of work done in the dry, where delay in placing is advisable or unavoidable, it should be limited so that the degree of set reached is not greater than will allow of ready and effective punning without the addition of further water. The permissible delay will vary with each case and must therefore be left to the experienced judgment of those in charge of supervision.

It is of interest to note that these results are to a large extent confirmed by recent research in England and the United States, which has shown that the strength of concrete revibrated after several hours suffers no appreciable injury and that at certain periods definite improvements in strength occurs.

Fuel Consumption of Rotary Lime Kilns.

IN order to economise fuel consumption in rotary lime kilns, Messrs. Edgar Allen & Co., Ltd., have put on the market an apparatus constructed in the form of a preheater and known as the Stag preheater. This is placed in the flue for the kiln waste gases, and consists of an inclined grate over which the crushed stone gravitates from an overhead bin. The inclination of the grate is adjustable to the angle of repose of the material, and the thickness of the stone on the grate may also be altered in accordance with the grading. The heated stone is collected in a small hopper under the bin, and then fed directly into the kiln at the required rate by an automatic feeder. The preheater contains no moving parts, the hot gases being forced through a bed of raw stone which absorbs the heat and cools the gases. No metal part is exposed to these hot gases until they have been cooled by their passage through the stone to a temperature harmless to metal. Tests show that the consumption of standard coal is 392 lb. per ton of burned lime, as compared with 470 lb. without the preheater. On the other hand there is a slight increase in power consumption, due to the necessity of driving the induced draught fan.

New Turkish Standard Specifications for Cement.

THE following is a translation of the new Turkish standard specifications for cement issued on March 5, 1937.

(Ia) Definition of Portland Cement.

Portland cement is a hydraulic cement. The product manufactured as follows shall be called Portland cement : A mixture of lime, alumina, and iron oxides shall be very finely ground and burnt at a temperature of 1,300 to 1,500 deg. C. to sintering. Not more than 3 per cent. of gypsum shall be added to the clinker and the whole shall be very finely ground.

(Ia_1) Varieties of Portland Cement.—There are two varieties of Portland cement, (1) Portland cement, (2) rapid-hardening Portland cement.[1]

(Ia_2) Composition.—The ratio of lime (CaO) to the total quantity of $SiO_2 + Al_2O_3 + Fe_2O_3$ shall not be less than 2 : $\frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3} \geqq 2$. (2) The ignited cement shall not contain more than 2·5 per cent. of sulphuric anhydride (SO_3) and not more than 4 per cent. of magnesia (MgO). (3) When the cement is treated with hydrochloric acid (HCl) the percentage of insoluble residue shall not exceed 0·85. (4) The total loss on ignition shall not exceed 3 per cent. (5) The cement shall not contain more than 3 per cent. of foreign ingredients (gypsum, etc.).

Portland-Blastfurnace Cement.

Portland-blastfurnace cement is a hydraulic cement. Granulated blastfurnace slag (slag cooled by water or steam) shall be mixed with Portland cement clinker so that the proportion of slag shall be 30 to 85 per cent. of the total. The ratio shall be determined according to the composition of the slag. The slag and the clinker shall be mixed and ground in the factory. The composition of the clinker shall be determined in accordance with the standard specifications for Portland cement.

(Ib_1) Varieties of Portland-Blastfurnace Cement.—There are two varieties of Portland-blastfurnace cement, (1) Portland-blastfurnace cement, (2) rapid-hardening Portland-blastfurnace cement.[2]

(Ib_2) Composition.—(1) The ratio between the total quantity of $CaO + MgO + 1/3Al_2O_3$ in the slag obtained as a secondary product when manufacturing iron and the total quantity of $SiO_2 + 2/3Al_2O_3$ must be less than 1 : $\frac{CaO + MgO + 1/3Al_2O_3}{SiO_2 + 2/3Al_2O_3} < 1$. (2) The quantity of gypsum added when

[1] The designations "Portland cement" and "rapid-hardening Portland cement" guarantee the minimum qualities according to the standard specifications. The difference between Portland cement and rapid-hardening Portland cement consists of the higher tensile and compressive strength of the rapid-hardening Portland cement from early ages.

[2] The designations "Portland-blastfurnace cement" and "rapid-hardening Portland-blastfurnace cement" guarantee the minimum qualities according to the standard specifications. The difference between Portland-blastfurnace cement and rapid-hardening Portland-blastfurnace cement consists of the higher tensile and compressive strength of the rapid-hardening Portland-blastfurnace cement from early ages.

grinding the slag and the clinker in order to regulate the setting time of the Portland-blastfurnace cement shall not exceed 3 per cent. of the final quantity of Portland-blastfurnace cement. (3) In the finished material the quantity of SO_3 shall not be more than 3 per cent. and the quantity of MgO shall not be more than 5 per cent. (4) The quantity of MnO in the slag shall not exceed 5 per cent. (5) When the Portland-blastfurnace cement is treated with hydrochloric acid (HCl) the percentage of insoluble residue shall not exceed 0·85. (6) The total loss of Portland-blastfurnace cement on ignition shall not exceed 3 per cent.

(II*a*) Fineness.

The residue on a sieve of 900 meshes per square centimetre (5,800 meshes per sq. in.) shall not exceed 1 per cent. The residue on a sieve of 4,900 meshes per square centimetre (31,600 meshes per sq. in.) shall not exceed 14 per cent.

(II*b*) Setting Time.

The initial setting time of the cement shall not be less than 1 hour. The final setting time shall not exceed 12 hours.[3]

(II*c*) Soundness.

The cement shall be tested for soundness by the Le Chatelier apparatus. After 4 hours' boiling in water the distance separating the indicator points of the apparatus shall not exceed 8 mm. (0·315 in.).

(II*d*) Specific Gravity.

The specific gravity of the Portland cement shall not be less than 3·05 and that of the Portland-blastfurnace cement not less than 2·8.

(II*e*) Tensile and Compressive Strength.[4]

The minimum strengths of the specimens composed of 1 part of cement and 3 parts of standard sand shall be in kg. per square centimetre (figures in brackets indicate the equivalent strengths in lb. per sq. in.):

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[3] The standard specifications refer only to cements the setting time of which is within the limits given in Clause II*b*. For special works special cements may be produced with longer or shorter setting time. In order to distinguish such cements from standard cements, such cements must have a label on the packings: "Quick setting cement" or "Slow setting cement."

[4] If no apparatus for testing the compressive strength is available the strength of the cement can be tested with the apparatus for testing the tensile strength only. If the tested cement has the minimum tensile strength according to the specifications it shall be called "Ordinary cement" or "Rapid-hardening cement." In doubtful cases testing of compressive strength is necessary. The cement must have both minimum strengths.

Strength.	1	2	3	4
	3 days in water.*	7 days in water.*	28 days in water.*	28 days combined storage (6 days in water, 21 days in air.†)
			CEMENT.	
Tensile	—	22 (313)	27 (384)	32 (455)
Compressive ..	—	300 (4,267)	350 (4,978)	400 (5,689)
			RAPID-HARDENING CEMENT.	
Tensile	27 (384)	—	34 (484)	42 (597)
Compressive ..	350 (4,978)	—	425 (6,045)	525 (7,468)

* After the specimens have been stored for 24 hours in damp air, they are kept in water of 18 to 20 deg. C. until they are tested.

† After the specimens have been stored for 24 hours in damp air, they are kept in water of 18 to 20 deg. C. for 6 days and for 21 days at an air temperature of 18 to 20 deg. C. The temperature of the room in which the tests are made must be under exact control.

(IIIa) Packing and Delivery.

(1) Cement shall be delivered (*a*) in wooden or steel drums; (*b*) in bags of paper, jute, or similar materials; or (*c*) without packing. (2) The net weight of the drums must be 200 kg. (440·9 lb.), and the total weight 210 to 214 kg. (463 to 471·8 lb.). The drums must be strong and must not leak. The net weight of paper or jute bags must be 50 kg. (110·23 lb.), and the total weight 50·25 to 50·5 kg. (110·78 to 111·33 lb.). (3) Losses during transport due to the packing must not exceed 2 per cent. (4) The printing on the drums, bags, or labels must contain the following data: (*a*) Name or trade mark of factory; (*b*) The colour of the label or printing on the bags must correspond to the variety of cement: for Portland cement the colour must be yellow; for rapid-hardening Portland cement, red; for Portland-blastfurnace cement, blue; for rapid-hardening Portland-blastfurnace cement, red-and-blue; (*c*) Year of manufacture; (*d*) Total weight; (*e*) Minimum tensile and compressive strength after 28 days. (5) Bulk cement shall be transported only in wagons, barges, and ships designed for the purpose. (6) Jute bags must be new; the seams must be inside and very strong. (7) Drums and bags must be closed, with a factory seal (bags known as "Ventilsäcke" do not require sealing). (8) The weight of bags must not exceed 1 per cent., and the weight of drums 7 per cent., of the total weight.[5]

(IIIb) Trade Customs.

(*a*) FOR SUPPLIES OF MORE THAN 200 TONS.—(1) Cement shall be stored in the factory in bags or drums in a closed dry store protected against the influence

[5] The customs authorities check whether imported cements comply with the standard specifications or not.

of the weather. Stocks for every order shall be stored separately. (2) Delivery, consignment, and all work necessary for taking samples from the bags or drums for testing shall be done at the expense of the manufacturer. (3) At the delivery of the goods the bags or drums must be in good condition. Cement damaged by moisture, in bags torn or with holes, or drums with damaged seals shall be refused. (4) Approval of deliveries of more than 200 tons can be made in the silo if desired by the vendor and purchaser.

(*b*) FOR SUPPLIES OF LESS THAN 200 TONS.—At examination for acceptance at the factory the purchaser may take samples and have them tested at his own expense. If the tests made in an official laboratory are unsatisfactory the vendor shall take back the cement and reimburse the carriage.

(*c*) FOR ALL QUANTITIES.—The weight of cement including packing shall be controlled by weighing of bags or drums as determined by the purchaser. The quantity to be weighed shall in no case be less than 5 per cent. or more than 7·5 per cent. of the total. In order to control the weight of bags and drums not more than 10 per cent. of the packing shall be weighed for each delivery. The tolerance in weighing cement and packing is 0·1 per cent. The vendor must provide certified weighing machines in good condition.

(IIIc) Samples for Testing.

If cement is supplied in bags or drums the quantity taken for testing shall not be less than 10 kg. (22 lb.) and shall be taken from 15 bags or 5 drums for each supply of 15 tons. If cement is supplied without packing 20 kg. (44·1 lb.) of samples shall be taken for each 50 tons. Samples from bags, drums, or silos, or from store without packing, must not be taken from the surface but shall be extracted by means of a tube from varying depths. After suitably mixing the samples taken from bags or drums for each supply of 15 tons, the mixture shall be divided into 3 parts and filled into glass or tinplate containers closed so that neither air nor water can get in and be sealed by both parties.[6] One of the samples shall be kept by the vendor, another by the purchaser and the third at a place agreed upon by both parties in order to make a check possible if necessary. If the results of tests do not comply with the standard specifications or with the required conditions the vendor may demand a repetition of the tests. The new tests must be made in the laboratory of an official research station. If the unsatisfactory results are confirmed acceptance shall be unconditionally refused by the purchaser. Refusal is justified if the result of one of the tests specified under sections I and II is not satisfactory and if a single one of the requirements is not fulfilled. The vendor must reimburse to the purchaser the costs of tests and carriage and the costs of loading and unloading if the cement has been unloaded and transported to another place. The purchaser must send back the condemned cement which must not be mixed with other cements. The cement used for tests shall not be paid for by the purchaser. The tests on the samples which have been taken must be made within three months.

[6] The two parties are the vendor and the purchaser. The vendor can be the manufacturer, the merchant, or an agent.

IV.—Method of Testing.

(*a*) Cement which has been delivered to a laboratory to be tested must be stored in the same condition in a dry room until the day of testing. If the container in which the cement is stored has been destroyed or damaged the form and condition shall be noted in the diary of the laboratory and no tests must be made with such samples. (*b*) Before beginning the tests the cement delivered in the làboratory shall be sifted in a sieve of 64 meshes per square centimetre (413 meshes per sq. in.). The residue on the sieve shall be noted. The cement which has passed through the sieve shall be mixed in suitable form and tested. (*c*) In order that the cement, sand, and water shall be of the same temperature, they must be stored 12 hours before the tests in the same room, the temperature of which shall be 18 to 20 deg. C. The maximum and minimum temperatures each day shall be noted in the diary. (*d*) Distilled or any other pure water (drinking water) may be used for the tests. The water may be measured by volume or by weight. The container in which the water is measured must be weighed after its inner surface has been wetted. (*e*) The form of the specimens and all operations during their manufacture must be the same and mechanised as far as possible.

(IV*a*) Specific Gravity.

The specific gravity of the cement shall be determined by the Schumann volumometer. The Schumann apparatus is a bottle-shape container with a capacity of 100 to 150 cubic centimetres (6·10 to 9·15 cu. in.). A calibrated glass tube is fixed at its mouth. The capacity of the tube is 50 cubic centimetres (3·05 cu. in.) and it is subdivided into 0·1 cubic centimetres (0·006 cu. in.). Both parts of the bottle shall be cleaned with alcohol and dried before use. After the lower part of the bottle has been filled with turpentine the glass tube shall be carefully inserted into the bottle. The tube fixed on the bottle shall be filled with a pipette up to the zero mark. Before the test the glass apparatus and the cement shall be kept for 6 hours in the same room in order to have the same temperature so as to avoid errors due to differences in temperature.

After the cement has been dried for one hour at 100 to 110 deg. C. and cooled, 100 gr. shall be weighed exactly to a milligramme. The cement shall be filled into the bottle by a piece of paper or a funnel. In order to prevent the cement sticking and blocking the instrument, the instrument must be continually lightly shaken. After all the cement has been filled in, the instrument shall be left for 20 to 25 minutes so that the air introduced into the oil while the cement was being filled in has time to escape. For determining the volume of 100 gr. of cement the level of the liquid shall be read off on the calibrated scale. The quantity of cement filled into the instrument is to be divided by the number of cubic centimetres which it fills and the specific gravity is thus determined, e.g. $\frac{100}{32{\cdot}6} = 3{\cdot}067$. After this test has been repeated several times the average shall be taken.

(IV*b*) Consistency[7] of Cement Paste.[8]

300 gr. of cement shall be filled into a metal dish of 20 to 30 cm. (8 to 12 in.) diameter by 8 to 10 cm. (3 to 4 in.) deep. In the centre of the cement in the dish a hole shall be made and filled with water, amounting to 23 to 30 per cent. of the cement. Then mixing and kneading shall immediately begin. The time of gauging shall be reckoned from adding water to the cement until commencing to fill the mould ; this must be not less than 3 minutes and not more than 4 minutes. The time for mixing and kneading only shall be 3 minutes from adding the water. For this work a spoon which conforms to the shape of the dish shall be used. The mixed and kneaded paste shall be filled into a ring of ebonite or metal of conical shape which rests on a glass or metal plate of about 12 by 12 cm. (4·72 by 4·72 in.).

The surface of the paste filled into this ring shall be smoothed off with a trowel level with the top of the mould. The cylindrical plunger of the instrument to be used for this test (Vicat apparatus) shall be carefully cleaned, dried, and lowered on to the glass plate. The pointer shall be adjusted to the zero mark of the scale. The cylindrical plunger of 1 cm. (0·393 in.) diameter shall be lowered on to the centre of the prepared paste. As soon as the plunger is in contact with the paste it shall be released and allowed to sink into the paste driven by its own weight. If the paste contains a sufficient quantity of water the plunger sinks until it is 5 to 7 mm. (0·2 to 0·3 in.) above the glass plate in half a minute. During the test the apparatus must be protected against shock. If necessary this test must be repeated with different quantities of water until the required consistency is reached. The quantity of water to be added shall be expressed as a percentage of the weight of the dry cement. The temperature of the water used has an influence on the setting time of the cement (higher temperature quickens the setting process, lower temperature slows it down).

The temperature of the cement used for setting tests must be controlled as well as the temperature of the water, the apparatus, and the room in which the tests are made. The temperature shall be 18 to 20 deg. C. The plunger of the apparatus and the screw of the plunger must work smoothly and the pointer must be at the zero mark of the scale as soon as the plunger touches the glass plate. The conical ring and the glass must be oiled before use.

(IVc) Determination of the Initial and Final Setting Time.

(1) The plunger of the apparatus used for determining the quantity of water required for the paste shall be replaced by the Vicat needle. A weight of 27·5 gr. shall be placed on the top of the apparatus. When the Vicat needle touches the glass plate the pointer must be at the zero mark of the scale. Before the needle is allowed to penetrate into the paste in the cone it shall be lowered into contact with the surface of the paste. In this position it shall be fixed by the screw at the side of the apparatus. By loosening the screw the needle is allowed

[7] It is essential to determine accurately the quantity of water.
[8] The paste is made by mixing neat cement and water.

to penetrate into the paste. At first, when the paste is still very soft, the screw fixing the needle must not be loosened suddenly so that it gets bent by knocking hard against the bottom. The initial set of the paste shall be determined with the needle completely free to move.

(2) To determine the initial setting time the needle shall be allowed to sink into the paste at intervals of five minutes. After the initial setting time has been determined the test shall be repeated every quarter of an hour in order to determine the final setting time. In order to avoid the needle striking the same spot twice, the position of the ring shall be altered after each test. The needle shall be carefully cleaned after each test with a rag or with filter paper. If any water accumulates on the surface of the paste it must be left there.

(3) The temperature of the room must always be registered in the diary. If the temperature of 18 to 20 deg. C. cannot be maintained in the laboratory, the tests must be conducted, in case of controversy, in a cabinet in which the temperature is 18 to 20 deg. C.

(4) The period elapsing between the time when the water is added to the cement and the time at which the needle sinks to a depth of 5 to 7 mm. (0·2 to 0·3 in.) above the glass plate shall be called the initial setting time. The final setting time is the period elapsing between the time when the water is added to the cement and the time at which the needle does not penetrate into the paste more than 1 mm. (0·04 in.). While determining the setting time the paste in the ring must not be shaken nor must its position be altered.

(IV*d*) Soundness.

The cement shall be tested for soundness by the Le Chatelier method. The apparatus for conducting this test must be as shown in the diagram[9]). This apparatus is made of brass. The thickness of its wall is 0·5 mm. (0·02 in.) and its internal diameter and height are 30 mm. (1·18 in.). The cylinder is split parallel to its axis. On either side of the split are attached two indicators with pointed ends of a length of 150 mm. (5·9 in.) welded exactly to the middle of the cylinder. The cylinder must be able to resist the following bending test: One of the indicators shall be fixed immediately near the weld with a clamp so that the other indicator is in a horizontal position underneath it. A weight of 300 gr. shall be suspended on the lower indicator immediately near the weld. The distance separating the indicator points shall then be increased by 15 mm. to 20 mm. (0·6in. to 0·8 in.). Before using the apparatus care must be taken not to allow the edges of the split and the indicators to be pressed against each other. The apparatus shall be placed on an oiled glass plate. When cement paste of normal consistency[10] is filled into the metal cylinder the indicators must be held together with a thread (near the welds) so that they do not alter their horizontal position nor stand apart.

After the surface of the paste has been smoothed off level with the top of the mould, the mould shall be covered with another glass plate upon which a small

[9] The apparatus has the usual form.
[10] In accordance with Clause IV*b*.

weight shall be placed. The distance separating the indicator points shall then be measured (*a*). This distance is the basis for determining the total expansion of the cement. The mould shall be carefully submerged in cold water without altering the position of the indicator points. The water shall have a temperature of 18 to 20 deg. C. The distance separating the indicator points shall be measured after final setting or 24 hours after filling the mould (*b*), and it shall be noted whether the distance (*b*) differs from the initial distance (*a*). The expansion (*b-a*) must not be more than 4 mm. (0·16 in.).

The glass plates covering the mould shall be carefully removed and the mould again submerged in cold water (with the indicators pointing upwards). Then the water containing the mould shall be brought to boiling point in 30 to 45 minutes and kept boiling for four hours. The container must remain covered while boiling proceeds. The quantity of water must be sufficient to make it unnecessary to add any to make up for evaporation. The distance separating the indicator points shall then be measured again (*c*).

The total expansion is (*b-a*) + (*c-b*). This test must be repeated three times for every cement and the average of the results shall be taken. The expansion (*c-a*) must not be moie than 8 mm. (0·315 in.).

(Va) Test for Fineness.[11]

The fineness of the cement shall be determined with sieves shaken by hand (*Figs.* 1*a* and 1*b*).[12] 100 gr. of cement dried at a temperature of 100 to 110 deg. C. shall be put on a No. 30 sieve, and the sieve shall then be covered. Air-set lumps shall be broken up with the fingers before the cement is put on the sieve. The cement shall be sifted for 25 minutes (shaking the sieve to the right) with approximately 120 movements per minute. After each 25 movements the sieve shall be turned horizontally through an angle of 90 deg. and the lower side of the sieve shall be tapped five times against a hard object. After sifting for 10 minutes the lower side shall be brushed with a small fine horse-hair brush to prevent the sieve from stopping up. After sifting for 25 minutes, if no more cement goes through the sieve, the residue shall be put on one side. The residue shall then be put into a container and weighed. The weighed residue in the container shall then be put back on to the sieve in order to check the weighing. The check shall be repeated until the difference in weight between two checks is less than 0·1 gr.

The residue on the No. 30 sieve shall then be put in the No. 70 sieve and sifted for five minutes without brushing or tapping the underside of the sieve. The residue shall be weighed and sifted once more for one minute in order to check it. This check shall be repeated until the decrease of the weight of the residue is less than 0·25 gr. The residues shall be expressed as percentages of the weight of the sifted cement.

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[11] Since the fineness of the cement has a very noticeable influence on the strength, the bond, and the density of mortar, the fineness must be tested very carefully.

[12] Corresponding to the German standard specifications. The sieve in *Fig.* 1*a* must be No. 30 (900 meshes per cm^2 = 5,800 meshes per sq. in.) ; the sieve in *Fig.* 1*b* must be No. 70 (4,900 meshes per cm^2 = 31,600 meshes per sq. in.).

These tests shall be repeated with 100 gr. of cement as just described. In the second test the residue on the No. 30 sieve must not differ from that in the first test by more than 1 per cent. of the total weight, and the residue on the No. 70 sieve must not differ by more than 0·3 per cent. of the total weight. If the differences amount to more than these figures the test must be repeated a third time. From these three tests the average of the two which are nearest to one another shall be taken. The dimensions of the sieves must be 22 cm. by 22 cm. by 9 cm. (8·56 in. by 8·56 in. by 3·55 in.). The wires of the sieve must be well stretched without destroying the regularity of the meshes.[13]

(Vb) Preparation of Mortar for Tests.

(1) The cement and sand shall be mixed in the ratio of 1 : 3 (by weight), 270 gr. of cement and 810 gr. of dry standard sand being filled into a hemispherical dish and mixed with a spoon which conforms to the shape of the dish. A prescribed quantity of water shall then be added.[14]

After this wet mixture has been mixed for another minute it is to be uniformly distributed into a mortar-mixing machine of the Steinbrück-Schmehr type and kneaded for twenty revolutions.

(2) 180 gr.[15] of standard mortar shall be filled into standard moulds shaped like the figure 8, and shall be hammered 150 times in the Böhme apparatus. Then the upper part of the mould shall be removed, and the surplus mortar shall be smoothed off level with the top of the mould with a knife or trowel, and the specimen marked. The mould shall be slid along the plate on which it rests and half-an-hour later the specimen shall be lifted up. The specimens shall then be put into a closed box, the atmosphere of which shall be of 90 per cent. relative humidity. Twenty-four hours (with a tolerance of two hours) after preparing the specimens, but in any case after the final setting time, the specimens shall be taken out of the box and put into water having a temperature of 18 to 20 deg. C. The volume of water must be at least four times as much as that of the specimens, and the water must stand 2 cm. to 4 cm. (0·8 in. to 1·6 in.) above the specimens. Soft water shall be used and renewed every fourteen days.

(3) The specimens when taken out of the water and dried in the air shall be stored on a shelf. They must not touch and must be stored in a room free from draughts. The temperature of the room shall be 18 to 20 deg. C. and its atmosphere shall be of 55 to 80 per cent. relative humidity.

(4) Immediately the hardened specimens have been taken out of the water the test must be begun, so as not to keep the specimens longer than 15 to 20 minutes in the air. Before the test they shall be dried slightly with a rag. They must not be shaken before and during the test.

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[13] The testing of the fineness of the cement may also be conducted with a sieve shaken mechanically.

[14] The necessary quantity of water to be added shall be determined by the formula : $\frac{1}{4}$ Y + 2·5 (Y is the percentage of water required for the cement paste of normal consistency in accordance with Clause IV*b*).

[15] More mortar than necessary for testing must always be prepared, since there is always a loss during the tests. In order to obtain good specimens the moulds must be well filled.

(5) Since the speed at which the load is increased has a great influence on the results the load shall be increased at the rate of 1 kg. per sq. cm. (14·22 lb. per sq. in.) in one second with a tolerance of $\pm$ 0·1.

(6) The ultimate strength of the mortar is determined by this test. The average of six tests is the tensile strength of the cement.[16]

(7) The moulds for the tests must be carefully cleaned and slightly oiled with special oil (two-thirds of rape-seed oil and one-third of petroleum) before use. If the moulds are greased too much this may affect the results of the tests unfavourably.

(8) The moulds must be made of non-corroding metal and each mould must be numbered. The moulds must be checked from time to time. The cross section at the narrowest part of the specimens shall be 22·3 mm. by 22·5 mm. (0·878 in. by 0·886 in.). A greater tolerance than $\pm$ 2 per cent. of the sectional area is not allowed.

(Vc) Apparatus for Testing Tensile Strength.

The tensile tests shall be conducted with the special apparatus.[17] The diameter of the shot shall be 2 mm. to 2·5 mm. (0·08 in. to 0·1 in.), and the speed at which the shot flows out of the container shall be 100 gr. in one second ($\pm$ 10). Before placing the specimen in the jaws of the apparatus, the operator must make sure that the knife-edges are in the correct position. The upper lever of the apparatus must be at the same level as the mark on the top of the apparatus when the can is not suspended. The weight of the can must not be more than 25 per cent. of the ultimate load.

(1) After the specimens have been taken out of the water and dried with a rag, they shall be placed in the jaws of the apparatus. The sides of the specimens and the ends of the jaws must fit exactly. When the specimens have been placed in the jaws a small weight shall be put on the upper lever and the long lever of the apparatus shall be adjusted to the mark by means of a screw. Care must be taken that there is not sand or any other foreign bodies on the specimen or in the jaws.

When the specimen has been placed as previously described and the can for the shot suspended, the small weight shall be removed from the lever and the shot shall be allowed to flow out. When the weight of the can and the shot has attained the breaking load, the can drops on the lever of the shot container underneath and stops the discharge.

(2) In order to determine the tensile strength of the cement the can and the shot shall be weighed to the nearest 10 gr. The result of multiplying this weight by 10 is the tensile strength in kg. per sq. cm. The tensile strength per sq. cm. of the average cross section of the specimen is obtained by the following calculation: The ratio of transmission of the lower lever is 1 : 5, and that of the upper lever 1 : 10. Therefore the total ratio of transmission of the levers is 1 : 50.

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[16] Reasons for extraordinary discrepancies, if any, must be noted in the diary.

[17] In accordance with the German specifications.

(3) The smallest cross section (in the centre) of the specimens is 5 sq. cm.

(4) By means of the upper lever a load, which is fifty times the original load, is transferred to the sectional area of 5 sq. cm. The load per sq. cm. of the area is :

$$\frac{P \times 50}{5} = P \times 10.$$

(V*d*.)—Test for Compressive Strength.

The compressive strength of the cement shall be determined as follows: 5,040 gr. of standard mortar (1,260 gr. of cement and 3,780 gr. of sand) shall be put into a mould.[18] The mortar shall be hammered in with 150 blows of the hammering apparatus as in the tests for tensile strength. (If the quantity of water is correct the water begins to leak out of the mould between the 90th and 100th blow.) The specimens prepared in this way shall be smoothed off level with the top of the mould and marked by means of a knife. The specimens shall be kept in a box in their mould (in contradistinction to the method used in the tensile tests.) The atmosphere of the box shall be of 90 per cent. relative humidity.

Approximately 20 hours after gauging the specimens shall be taken out of the mould, and after 24 hours they shall be put into water at a temperature of 18 to 20 deg. C. The surface of the water shall be 2 cm. to 4 cm. (0·8 to 1·6 in.) above the specimens. The water shall be renewed every fourteen days. The specimens to be hardened in the air shall be stored on bars of triangular cross section not in contact and in a room free from draughts. The temperature of the air shall be 18 to 20 deg. C., and the atmosphere shall be of 55 to 80 per cent. relative humidity. The specimens stored in water shall be taken out shortly before testing and slightly dried. The compression of the machine used for this test shall be exact to 1·5 per cent. The compressive strength of the cement is the average of tests with six specimens.

The pressure shall be exerted on the sides of the cubes, and since the speed at which the load is increased has a great influence on the results, the load shall be increased at a rate not exceeding 20 kg. per sq. cm. (284·5 lb. per sq. in.) per second. The machines used for this test must increase the load uniformly and without shocks until the specimens break, and the specimens must be placed in the machine in such a way that the load shall always act in the centre line of the specimen.

The temperature and humidity must be controlled during the preparation of the specimens in the laboratory. The moulds for the compressive tests must be well cleaned and slightly greased with a special oil before use in the same way as the moulds for the tensile tests.

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[18] In accordance with the German specifications.

(VIa.)—Standard Sand and Apparatus for Testing Sand.

Experience has proved that the chemical and physical properties of the sand used for mortar have a considerable influence on the strength of the mortar. In order to make it possible to conduct uniform and comparable tests it is necessary that the sand used in the laboratories shall be of the same quality, that the grains have the same dimensions and the same shape, and that the sand has a constant weight per unit of volume. Turkish standard sand is obtained in the "Sultan Tchiftlik" pit opposite the Isle of Marmara.

The raw sand shall be washed very carefully in a drum and dried in a cylinder heated with steam (at about 120 deg. C.). The dried sand shall be freed of rough pieces by means of a rake and shall be sifted through two sieves, one above the other, the meshes of which have certain given dimensions. The residue on the lower sieve is the standard sand.

The standard sand must comply with the following requirements: (1) The quantity of SiO_2 shall be not less than 92 per cent. (2) The quantity of particles which can be washed off shall not exceed 0·05 per cent. (3) The residue on a sieve with 1·39 mm. (0·055 in.) apertures shall not exceed 2 per cent. (4) Not more than 5 per cent. must pass through a sieve with apertures of 0·74 mm. (0·029 in.).

The diameter of the grains shall be determined by means of metal sieves complying with the following requirements: (1) The thickness of the sieve plates must be 0·25 mm. (0·01 in.) with a tolerance of $\pm$ 8 per cent. (2) The apertures must have diameters of 0·74 mm. (0·029 in.) and 1·39 mm. (0·055 in.) respectively.

Eight to ten apertures shall be measured and checked at three or four different places in consecutive rows on the sieves. The mean dimensions must not differ from each other by more than 2 per cent., and the diameters of the apertures shall not differ from the required dimensions by more than 5 per cent. The measurements of the apertures of the sieves must be exact to 0·01 mm. (0·0004 in.).

(3) The smooth surface of the perforated plate must be at the underside of the frame.[19]

(4) The size of the sieves shall be 10 cm. by 10 cm. (3·93 in. by 3·93 in.).

(VIb.)—Testing Standard Sand.

The sand to be tested shall be dried for one hour at a temperature of 100 deg. C. Two gr. of this sand shall be weighed in a porcelain dish. To this 20 c.c. (1·22 cu. in.) of hydrochloric acid of a specific gravity of 1·16 and 20 c.c. (1·22 cu. in.) of distilled water shall be added. The mixture shall be heated for one hour on a water bath and filtered. The mixture shall then be carefully washed with hot water, dried and ignited. The loss of weight shall not exceed 0·25 per cent.

These standard Specifications apply to all cement sold in Turkey.

[19] After drilling the holes the sieves must not be polished.

Selecting a Motor for Cement Mill Drive.

LOW FIRST COST OR LOW RUNNING COST ?

[CONTRIBUTED]

A TENDENCY to dwell too much upon the first cost of machinery, as compared with the service it is likely to give and therefore its running cost, is a mistaken policy, particularly in the case of motors which are operating more or less continuously, such as those in cement mills, where the motor may be running at or near full load for 140 to 160 hours per week. In many such cases synchronous motors can be used to advantage because of their unity power factor operation (or power factor correction capabilities) and their higher efficiency. For example, for a rating of more than about 500 h.p. at 750 r.p.m. a salient-pole synchronous motor operating at unity power factor is more efficient than an induction motor, with or without a phase advancer, and hence offers the best service as regards running costs.

In many cases, notably where the cost of power is high or where operating hours are long, a user is justified in paying more for a machine having a higher efficiency than a cheaper machine. The leading makers offer machines designed to reduce the losses as much as possible, e.g. special low-loss high-silicon steel for the stator laminations, stator windings arranged to give low eddy-current loss, and ventilating fans designed for low power loss.

For many years a synchronous-induction motor has been built which can be used for any drive to which a constant-speed motor can be applied, and which can start against 1.5, 2.0 and 2.5 times full load torque. This motor has the usual three-phase starting winding brought to slip-rings on the rotor, but in addition has an excitation winding arranged on salient poles below the starting winding and requiring only a relatively low excitation current. With this type of motor, exceptionally high efficiencies can be obtained—much higher than are obtainable with the older type of synchronous induction motor which is, after all, only a compromise, seeing that the excitation winding has to serve for the starting winding as well. For example, a 1,200-h.p. synchronous-induction motor of this type has recently been built for a cement mill drive, designed to operate on a 3-phase, 50-cycle, 3,150-volt supply and running at 750 revolutions per minute. It has all the special features mentioned and on test its full load efficiency was found to be 97.6 per cent. at unity power factor. This efficiency is obtained by the "segregation of losses" method, all losses including stray load losses being measured on the motor and included in the efficiency calculation. The difference in full-load losses of these motors is then 9 kW., the annual cost of which (at 0.25d. per unit) is £75.

Enclosures for Industrial Motors.

[CONTRIBUTED].

THE use of electric motors for industrial drives under unfavourable conditions has led to the development of enclosures to protect the motor so that it will not have to be frequently dismantled for cleaning and other attention. The tendency is towards mounting the smaller motor direct to, or building it into, the machine it is to drive. In many cases the machine can be designed to provide adequate protection for the motor. There are cases, however, where this is not possible, and the motor must withstand the conditions under which it has to work.

In the past the choice of motor has been limited, broadly speaking, to the open-type machine, the pipe-ventilated machine (for which air trunking is required), and the totally-enclosed machine. The size and cost of the last named were often prohibitive, but with the advent of the totally-enclosed fan-cooled motor these difficulties have been overcome. The protected or screen-protected motor is well ventilated and can be used on most drives where it is free from excessive dust, oil, and moisture.

The totally-enclosed machine for small horsepowers and the totally-enclosed fan-cooled machine for larger horsepowers have been developed for dirty conditions where open-type motors are unsuitable. With the use of fan-cooling on all but the smallest motors, the enclosed machine is very little larger than the open machine of the same rating. The enclosed machine should be used in all situations where there is excessive dust and other foreign matter. This enclosure can also be used for motors working where they are likely to encounter splashing water, as they are weatherproof as well as enclosed.

Despite the use of improved insulating materials, breakdowns are often due to the entrance to the windings of harmful dusts, liquids, fumes, etc. For example, fine metallic dust from grinding machines will penetrate end-winding insulation, whether the insulation is in the form of taping or compound. It penetrates also into the slot past the wedges, frequently causing breakdowns in the slot and consequent damage to the core, while in addition it provides an earth leakage path from the end-windings to the core. Another danger is of the dust being drawn into the air gap, thereby causing rubbing between the stator and the rotor. This may also result in fire, as fine metallic dust, apart from its conductive properties, will ignite readily at relatively low temperatures.

Where an enclosed machine is not permissible, and the motor is to operate under arduous conditions, special insulation treatments can be provided as additional protection to the windings. It should be noted, however, that such additional treatment can only delay the deleterious effect of harmful foreign matter, so that frequent cleaning will also be necessary.

In many mills the presence of large quantities of dust necessitates a full measure of protection for the internal parts of electric motors. In the past such protection has usually been given by using a totally-enclosed motor, or a motor

of the pipe-ventilated type, to which cooling air is supplied through pipes or ducting; alternatively, it has sometimes been convenient to use ordinary protected motors in special housings or enclosures. Totally-enclosed motors are large and costly, whilst, unless the piping is short, pipe ventilation is often inconvenient, unsightly, and expensive. An economic alternative is the closed-air-circuit motor, which combines the features necessary for satisfactory operation in such situations and has the advantage of total enclosure at little more than the price of the ordinary protected type. The closed-air-circuit motor comprises a pipe-ventilated type of machine with the inlet and outlet openings connected to a surface-cooled radiator instead of to the outside atmosphere. This allows continuous air circulation driven by the rotor fan through a closed circuit, and gives total protection of the vital parts from the surrounding atmosphere.

The surface-cooled radiators consist of groups of straight tubes welded into end-plates and arranged in such a way that, while the heated air within the motor casing passes over the exterior of the tubes, an ample stream of cold outside air is forced continuously through the inside of the tubes by means of a second fan mounted on the non-driving end of the shaft outside the totally-enclosed casing of the motor. This air is directed through the tubes by means of an elbow-joint between one end of the radiator and the fan casing. Moreover, the two streams of air that pass over the outside and inside of the tubes flow in opposite directions, and, as the two streams are separated only by the walls of the tubes, efficient and rapid cooling is maintained. Very little dirt can lodge in the ventilation system since the tubes are smooth and straight and, as the elbow-joint is easily detachable, a flue brush only is necessary to clear the external air passages which alone are exposed to the atmosphere.

Tablet in Memory of the Inventor of Portland Cement.

A note on the unveiling of this memorial at Wakefield was given in our last number.

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